The Thermal Test and Analysis of Envelope in Existing Buildings

Xiaoyan Liu Xiaoqing Li Jiangang Sun Zhen Wang
Professor Graduate Professor Professor
Civil Engineering College of Daqing Petroleum Institute, Daqing, 163318
li964499@sina.com

Abstract: This paper deals with the project to improve existing building energy efficiency. Building energy efficiency is an international topic that includes many aspects. There are more than 43 billion square meters of existing buildings in China, so how to improve the health and comfort and minimize the energy consumption costs of existing buildings is quite important. Improving existing buildings can be divided into two parts, envelope and heating system. Much research has been done on building conservation during the past 30 years in China. The structure of envelopes is improved, and many new energy efficiency materials are used in buildings while some other foreign researchers have developed several kinds of software for the analysis of building energy conservation.

In this paper, we report on the results of heat transfer loss tests in existing buildings in Daqing, including the walls, doors, windows and the floors. The areas with most heat loss areas are pointed out, and the objective of reducing the heat cost is discussed. The design for improving the structure of existing buildings for reduced energy consumption costs was provided. The energy consumption cost in existing buildings can be reduced by up to 30% through these improvements.

Key words: thermal test; analysis; envelop

1 INTRODUCTION

The performance of building envelop is reflected by the energy costs, thermal comfort, and air quality of building. In order to get the result of the energy costs, thermal test is necessary.

Major requirements that influence building envelop performance include: control of heat flow, control of air flow, control of water vapor flow, control of rain penetration, control of light, solar and other radiation effects, control of noise, control of fire, provision of strength and rigidity, durability, and aesthetics [1].The environmental chamber is the first of its kind in Canada and is unique in concept. It is located in a specially constructed laboratory of the Centre for Building Studies (CBS), in downtown Montreal [2]. Fiber-reinforced plastic(FRP) materials are being more frequently used in building construction. A testing program was developed to investigate the thermal characteristics of a tongue-groove fiberglass composite panel system [3]. Otherwise, some test such as fire resistance of walls and floors in Japan [4], the test for effect of moisture on hygrothermal and energy performance of a building in Poland [5] are both carried out.

In this paper ,we have found out the main heat loss part of a existing building, and we have also given out the rebuilt design advice. The heat loss were both analyzed before and after rebuilt.

2 THERMAL TEST PROCESS

We have tested the temperature on the surface both inside and outside the building. The heat transfer loss has also been tested. 17 representative temperature-tested point was disposed, and 8 heat flux-tested point was also disposed. The test lasted 5 days[6].

The temperature inside and outside the buildings, and the temperature on the surface of the buildings, and the heat transfer loss through the buildings' envelop (including the walls, doors, windows beams and the floors) have all been tested. Three representative house on different floors (the first floors, the standard floors and the top floors) were chosen for testing. The number is 3-1-1-101, 3-3-3-301, 3-2-3-501.

The temperature sensor for testing is T-type thermoelectric couple, and the heat transfer sensor is WYP, WYP1, and WYR heat transfer flake. There are

98 temperature-tested points and 70 heat flux-tested points. 2.2 Test process

The test last for 15 days. The data were recorded every 5 minutes, and more than 1,200,000 were collected. According to these data, we could conclude the change trend of the data along with time. Then the heat transfer coefficient and heat cost could be calculated. It could help us to analysis the potential capability of energy conservation and design the energy conservation program.

3 THE RESULT AND ANALYSIS OF THERMAL TEST

3.1 The Average Temperature of Each Points

According to the data, take 3-1-1-101(1 day) as an example. Fig1 is the temperature inside and outside south living room and on the surface of south wall both outside and inside.

According to the curve in Fig. 1, we could conclude that the temperature inside living room and on the surface inside the wall is stable, while the trend of the temperature outside living room and on the surface outside the wall is like a sine wave.

3.2 The Average Temperature Per Day Both inside and outside the Building during the Test.

According to the data, the temperature changes from 13.5 to 21.7℃,only the temperature of kitchen and hall is below 16℃, others' is above 16℃. So the temperature could almost meet the require of the standard.

3.3 The Heat Transfer Coefficient of Various of Envelop

Heat loss, temperature inside and outside the building, heat transfer coefficient and thermal resistance are calculated and the result is in Tab. 1.

Average heat transfer coefficient of the wall could be calculated by equation 1

$$K_m = \frac{K_p \cdot F_p + K_{B1} \cdot F_{B1} + K_{B2} \cdot F_{B2} + K_{B3} \cdot F_{B3}}{F_p + F_{B1} + F_{B2} + F_{B3}} \quad (1)$$

K_m ——Average heat transfer coefficient of the exterior wall, $W/(m^2 \cdot K)$;

K_p ——Average heat transfer coefficient of the main exterior wall body, $W/(m^2 \cdot K)$;

K_{B1}、K_{B2}、K_{B3} ——Heat transfer coefficient of the thermal bridge on exterior walls, $W/(m^2 \cdot K)$.

F_p ——Area of the main exterior wall body, m^2;

F_{B1}、F_{B2}、F_{B3} ——Area of the thermal bridge on exterior walls, m^2。

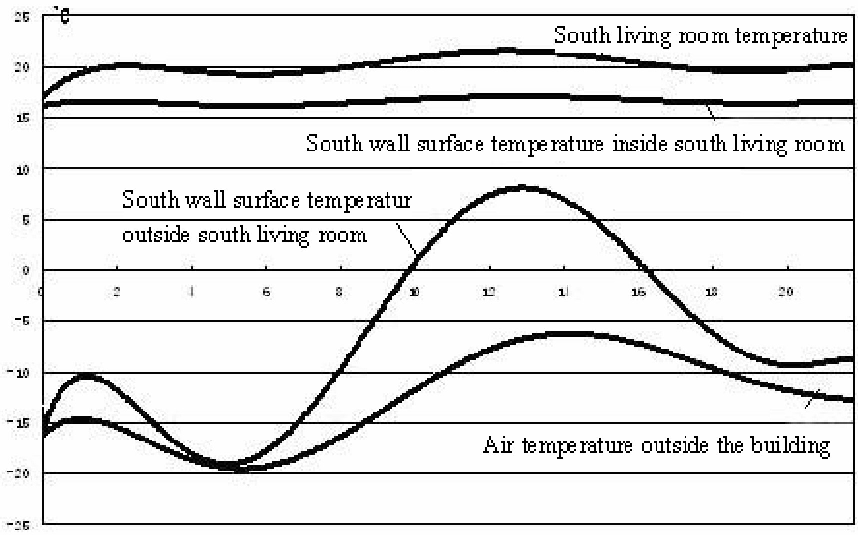

Fig. 1 Temperature inside and outside south living room and on the both surface of south exterior wall.

Tab. 1 The heat transfer parameter of various of building envelop

	Temperature inside	Suface temperature inside wall	Suface temperature outside wall	Air temperature outside	Heat flux	Heat transfer coefficient
South wall of living room	21.7	17.3	-7.3	-11.9	40.22	1.197
Beam of south wall in living room	21.7	20.9	-5.0	-11.9	65.90	1.960
East wall of east bedroom	19.9	16.6	-9.9	-12.9	36.06	1.184
Beam of east windows in east bedroom	19.9	15.8	-9.2	-12.9	61.22	1.866
North wall of north bedroom	19.5	14.9	-11.3	-13.8	43.96	1.320
Beam of north windows in north bedroom	19.5	15.9	-12.1	-13.8	60.41	1.825
door	16.8	13.3		2.4	29.62	2.060
North balcony door	15.9	9.6		-10.6	31.40	1.185
South windows of living room	21.7			-11.9	103.30	3.070
North bedroom windows	19.5			-13.8	106.10	3.190
East bedroom windows	19.9			-12.9	113.75	3.468
Living room floors	21.7	16.1			10.12	0.795
North bedroom floors	19.5	15.0			8.90	0.845
East bedroom floors	19.9	17.0			7.21	0.825

The heat transfer coefficient of envelop in the standard are shown in Tab. 2[7].According to the standard, the heat transfer coefficient of the existing buildings has overstepped the limit of standard. The heat transfer coefficient of the roof has overstepped 174%, the wall's has overstepped 140%, the windows' have overstepped 30%, and the floor has overstepped 173%.

Compared to the energy conservation buildings, in order to keep the temperature inside above 16℃, it needs more energy. Most of the energy lost through the envelop. It's a serious waste of energy. So it's in dire need of energy conservation rebuilt for these existing buildings.

4 REBUILT PROJECT

The rebuilt project is add a piece of polystyrene slab to the envelop of existing buildings (roof, wall and floor). The thickness of polystyrene slab is in Tab .3.

The temperature and the heat flux distributing of wall are shown in Fig.2 and Fig.3.

Tab. 2 The heat transfer coefficient limit of building envelop in Daqing

parameter / position	roofs	exterior walls	windows	doors	floors
heat transfer coefficient, W/（m^2 •K）	0.50	0.52	2.50	2.50	0.3

Tab .3 The thickness of polystyrene slab on envelop

parameter / position	heat transfer coefficient of buildings, W/（m^2 • K）	heat transfer coefficient of standard, W/（m^2 • K）	thickness of polystyrene slab, mm
roofs	1.37	0.50	57
walls	1.25	0.52	51
floors	0.82	0.30	95

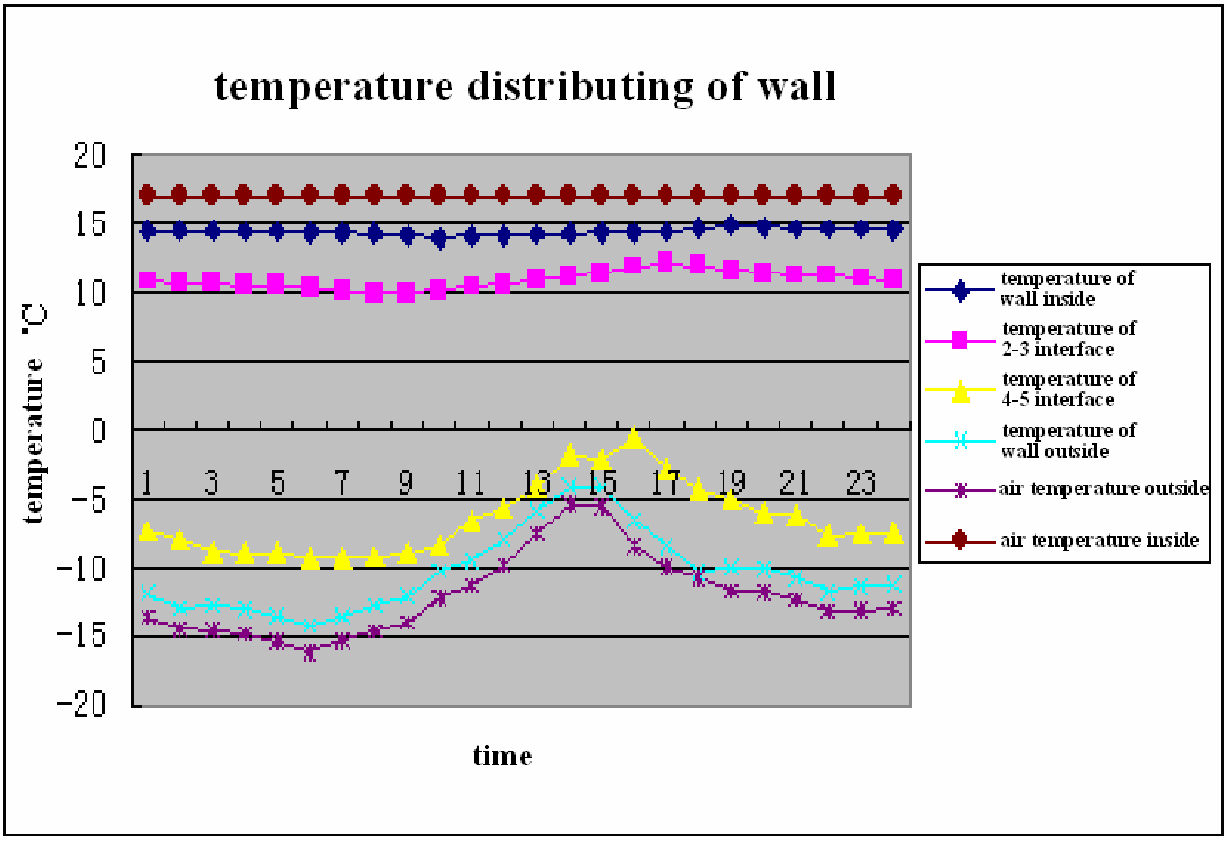

Fig.2 The temperature distributing of wall

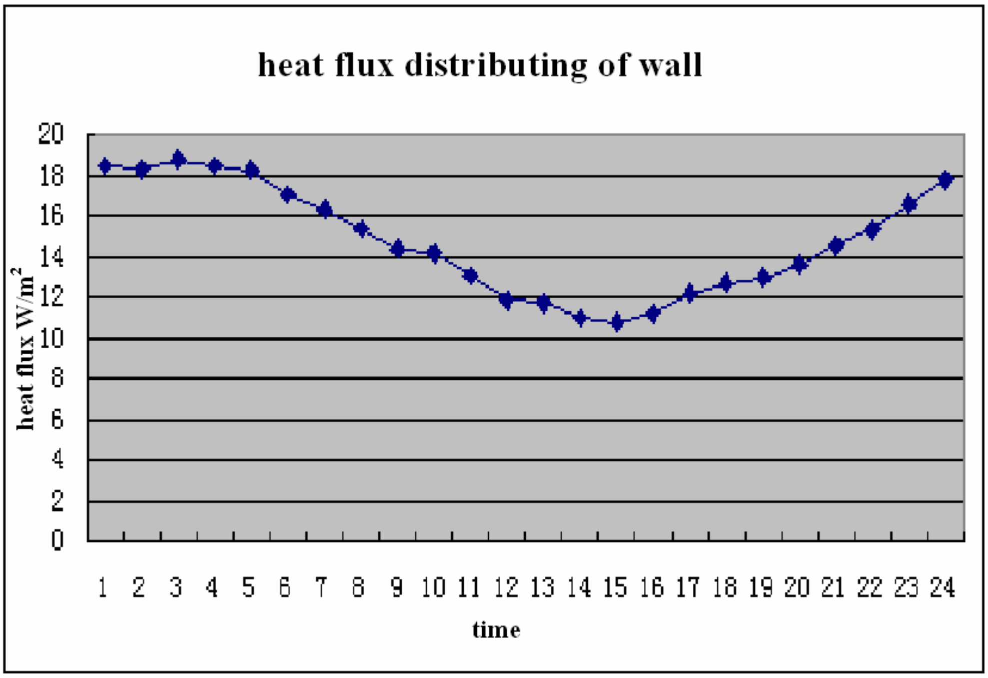

Fig3. The heat flux distributing of wall

5 CONCLUSIONS

Through the thermal testing, calculation and

(1) The heat transfer coefficient of the existing buildings has overstepped the limit of standard. The heat transfer coefficient of the roof has overstepped 174%, the wall's has overstepped 140%, the windows' have overstepped 30%, and the floor has overstepped 173%.

(2) The thermal resistance of the walls is 0.80(m^2 • K/W), the thermal resistance of the roofs is 0.73(m^2 • K/W), both of them haven't get the minimum thermal resistance of standard. The roof is more serious. The thermal resistance of the roofs is only 83% of the minimum thermal resistance. It's easy to dew on the surface of envelop, and it will influence the performance of envelop.

(3) The heat cost of the buildings (take 3-1 as an example) is 155557.0W. While 82.8% is the heat transfer cost, it's 128806.7W. The roof thermal energy cost is 13.9%. The wall's is 26.9%. The partition walls of staircase is 7.4%. The door's is 1.3%. The windows' is 21.9%. The floor' is 8.6%. Air penetrate thermal energy cost is26750.3W, it's 12.7%.

(4) The building heat cost index is 46.32W/m^2, but the limit of building heat cost index in Daqing is 22

analysis of existing buildings, we have given out these conclusions.

W/m^2. So it has serious overstepped the limit.

(5) In order to reduce the heat cost index to the limit, a piece of polystyrene slab is added to the envelop of existing buildings (roof, wall and floor). The thickness roof, wall and floor is 57mm, 51mm and 95mm.

REFERENCES

[1] Hutcheon, N.B. Requirements for exterior wall.[J] Canadian Building Digest, Vol. 48, Nat. Res.Council, Div. of Build. Res. Canada, 1963.

[2] Paul Fazio, Member, ASCE, Andreas K. Athienitis, Cedric Marsh, Jiwu Rao. Environmental Chamber for Investigation of Building Envelop Performance [J].Journal of Architectural Engineering/June, 1997,97-102.

[3] Ossama A. Abdou. Thermal Performance of an Interlocking Fiber-Reinforced Plastic Building Envelop System. [J]Journal of Architectural Engineering/March, 1997, 9-14.

[4] Y. Sakumoto,T. Hirakawa, H. Masuda, K. Nakamura Fire Resistance of Walls and Floors Using Light-Gauge Steel Shapes[J]. Journal of Structural

Engineering/November , 2003, 1522-1530.

[5] Dariusz J. Gawin, D.Sc. Marcin Koniorczyk, Aldona Wieckowska, Ph.D. Elisabeth Kossecka, D.Sc. Effect of Moisture on Hygrothermal and Energy Performance of a Building with Cellular Concrete Walls in Climatic Conditions of Poland. [J] ASHRAE Transactions, 2004, 795-803.

[6] Wang Zhen, Liu Xiaoyan, Zhang Yongyi, Cai Yingwei, Gong Haiying Optimization of energy conservation design of constructional enclosing construction[J] Journal of Daqing Petroleum Institute 2001, 25 (1):95～97(In Chinese)

[7] Energy conservation design standard for new heating residential buildings JG9 26—95(In Chinese)